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(54) Title: BEVELING TOOL FOR OPTICAL FIBERS			
<p>(57) Abstract</p> <p>A tool (10) for generating a beveled end (32) on an optical fiber (34). The tool (10) comprises a base (12) having an abrasive surface (18), and an arm (14) supporting an adapter (16) which secures the terminal portion of the fiber (34) to be beveled. The arm (14) is attached to the base (12) in such a manner as to provide relative translational movement between the arm (14) and the abrasive surface (18). In one embodiment, the abrasive surface (18) is found along a wall of a circular channel (20) formed in the upper end (22) of the base (12). In other embodiments, the abrasive surface (18) is generally planar, either formed directly on the base (12), or formed on a platter which is attached to the base (12). A motor may be provided to induce movement of the platter, via a crank arm or pulley system. The operator may impart a precise bevel (i.e., a predictable included angle and end face diameter) by setting the length of the fiber extending from the adapter, and by rotating the arm or platter a certain number of turns. When the fiber adapter (16) is oriented orthogonal to the abrasive surface (18), but the length of the fiber extending from the adapter (16) is greater than the distance between the adapter (16) and the abrasive surface (18), the fiber (34) bows near its terminal end (32), and its resilience provides the force needed to grind down the periphery of the end face. The tool (10) may be designed to avoid rotation of the adapter (16) (from an absolute frame of reference), thereby precluding unnecessary torsional stress in the fiber (34).</p>			

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BEVELING TOOL FOR OPTICAL FIBERSBackground of the Invention1. Field of the Invention

5 The present invention generally relates to optical fibers, and more particularly to the preparation of a terminal end of an optical fiber which is to be connected to another fiber or an optical device.

2. Description of the Prior Art

10 In recent years, optical fiber has surpassed copper as the preferred medium for telecommunications. Optical connectors and splices are used to interconnect fiber optic cables, and to terminate fibers at electro-optical devices. A "connector" often refers to a device
15 which allows repeatable engagement and disengagement of the cable, while a "splice" typically refers to a device which is used for the permanent attachment of two cable ends. These terms should not, however, be construed in a limiting sense as used herein since the present invention
20 is applicable to all classes of fiber optic interconnection devices.

There are several different kinds of connectors and splices, including ferrule or biconic connectors, and fusion or mechanical splices. In each of these devices,
25 the terminal end of the fiber is physically prepared in order to optimize transmission of the signal at the interface between adjacent fibers (or between a fiber and an electro-optical component). For example, the fiber ends are usually cleaved and/or polished. It has also
30 been found that beveling (chamfering) the end face of the fiber may improve connector performance. As shown in Figure 1A (in which the angles of the end faces are exaggerated for purposes of illustration), if the end faces are not perfectly parallel, there will be a slight
35 gap at the center of the fibers, where the entire signal travels along the innermost core. This is usually the case when the fibers are simply cleaved and not polished.

As further illustrated in Figure 1B, signal transmission usually improves (insertion loss is lower)

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with beveled fibers, in part due to the smaller longitudinal separation s at the fiber centers. In Figure 1B, the fibers have been cleaved and beveled, but not polished. In this regard, the term polishing refers to grinding the entire surface of the fiber end face, particularly the central portion thereof. In contrast, beveling (or chamfering) only grinds the periphery of the fiber or, alternatively, leaves a central portion of the end face untouched. There are also fewer problems when inserting a beveled fiber into a connector or splice. For example, the fiber is less likely to skive or scrape material from a splice element formed of a soft material, such as aluminum.

The primary method in the prior art for imparting a bevel to a fiber is depicted in Figure 2. In that method, an abrasive pad 1 is mounted on a grinding wheel 2 attached to a spindle or shaft 3. A collet 4, which is spatially fixed with respect to wheel 2, holds the fiber 5 to be beveled. Collet 4 is provided with a gear 6 which causes fiber 5 to rotate as it contacts pad 1. This device has several significant disadvantages. Since the collet is fixed with respect to the grinding wheel, it is very limited in the bevel geometry it can generate. Specifically, since the distance from collet 4 to pad 1 is constant, the length of fiber 1 extending from collet 4 is likewise constant. Also, the angle of inclination of collet 4 is fixed. These limitations preclude wide selection of end face diameters and included angles of the bevel surface. Additionally, rotation of collet 4 via gear 6 induces torsional stress on that portion of the fiber leading away from the device, which could damage the fiber and even lead to breakage.

Another grinding method similar to beveling is taught in U.S. Patent No. 4,766,705, but that technique is considered generally unsuitable for most connection applications since it produces a chiseled end face rather

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than a conical bevel.

In some instances, the performance of beveled (unpolished) fibers exceeds that of polished fibers. Beveling may eliminate the time and expense associated 5 with polishing, but it is of less overall benefit if the beveling process is more demanding than polishing. It would, therefore, be desirable and advantageous to devise a simple apparatus for quickly imparting a beveled finish to the end face of an optical fiber. Such an apparatus 10 should, however, overcome the limitations of the device shown in Figure 2 relating to the geometry of the bevel and torsional stress on the fiber.

Summary of the Invention

15 The present invention provides a bevel generating tool generally comprising a base having an abrasive surface, an arm rotatably mounted to the base, and an adapter securing the terminal portion of the optical fiber, the adapter being removably attached to 20 the arm. The abrasive surface is formed on the base such that the surface is oriented at a non-orthogonal angle with respect to the axis of rotation of the arm, i.e., the abrasive surface is either parallel with this axis, or oriented at an oblique angle with respect thereto. 25 The abrasive surface may be formed along a wall circular channel formed in the upper end of the base, the wall being either generally cylindrical or generally conical in shape. In the preferred embodiment, the arm has a hole therein for receiving the adapter, and the hole is 30 skewed with respect to the plane defined by the arm. The arm may be fixed to a shaft which is rotatably mounted to the base, and its effective length may be adjusted. Optical fibers having beveled end faces exhibit improved 35 performance in both multimode and singlemode applications, and in both discrete (single) and multifiber connectors and splices. Beveled fibers may be used with or without index matching gel. The beveling process is

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simple and may require less than a minute to complete per fiber. Beveling may be performed manually or with a motorized tool.

5 Brief Description of the Drawings

The novel features and scope of the invention are set forth in the appended claims. The invention itself, however, will best be understood by reference to the accompanying drawings, wherein:

10 Figure 1A is a side elevational view of the interface between two optical fibers having cleaved end faces;

15 Figure 1B is a side elevational view of the interface between two optical fibers having beveled end faces;

Figure 2 is a side elevational view of a prior art fiber beveling machine;

20 Figure 3 is a sectional view of one embodiment of the optical fiber beveling tool of the present invention;

Figure 4 is a top plan view of the beveling tool of Figure 3, with the fiber adapter omitted;

25 Figure 5 is a front elevational view of another embodiment of the optical fiber beveling tool of the present invention;

Figure 6 is a front elevational view of the beveling tool of Figure 5, but the adapter arm has been rotated 90° to illustrate the fiber bow;

30 Figure 7 is a partial sectional view along lines 7-7 of Figure 5, depicting angle polishing of the previously beveled fiber;

Figure 8 is a sectional view of an alternative abrasive surface for the embodiment of Figure 4;

35 Figure 9 is top plan view of yet another embodiment of the optical fiber beveling tool of the present invention;

Figure 10 is a sectional view along lines 10-10

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of Figure 9;

Figure 11 is sectional view of an alternative fiber adapter;

5 Figure 12 is a sectional view of still another embodiment of the optical fiber beveling tool of the present invention;

Figure 13 is a top plan view of the beveling tool of Figure 12, depicting its cover assembly;

10 Figure 14 is a top plan view of the tool of Figure 12, with the cover assembly removed, illustrating movement of the abrasive media platter and cam slide; and

Figure 15 is a sectional view of a further embodiment of the optical fiber beveling tool of the present invention, similar to that of Figure 12.

15

Description of the Preferred Embodiment

With reference now to the figures, and in particular with reference to Figures 3 and 4, there is depicted one embodiment 10 of the fiber beveling tool of the present invention. Tool 10 is generally comprised of a base 12, a rotating fiber adapter arm 14, and a hand-held fiber adapter 16. Base 12 has an abrasive surface 18 formed thereon for grinding the fiber end periphery during the beveling process. In the embodiment of tool 10, abrasive surface 18 is defined by the outer wall of a circular channel 20 formed at the upper end 22 of base 12 (it could also be formed along the inner wall of channel 20). The abrasive nature of surface 18 may be created using either loose particle abrasives or micro-abrasive film adhesively secured to the outer wall of channel 20. One film appropriate for this use is the micro-abrasive paper sold by Minnesota Mining and Manufacturing Co. (3M --assignee of the present invention) under the designation Imperial Lapping Film (with grit sizes varying from 0.3 μm to 5 μm ; grit material may include aluminum oxide, cerium oxide, silicon carbide and diamond). Base 12 may be constructed of any durable material, such as

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polycarbonate or aluminum.

Arm 14 is fixed to a shaft 24 which is rotatably mounted in base 12 by means of bearings 26, spacers 28 and C-clip 29. A set screw 30 may be used to 5 adjust the effective length of arm 14, i.e., the proximity of the end 32 of fiber 34 to surface 18. In an equivalent design, arm 14 could be rotatably mounted to base 12 without the need for a rotating shaft. Arm 14 is releasably attached to shaft 24 by retainer screw 36.

10 Arm 14 and shaft 24 may also be constructed of any durable material, preferably a metal such as aluminum or stainless steel.

Arm 14 has a hole 38 therein near its distal end 40, for receiving fiber adapter 14. Hole 38 does not 15 extend normal to the plane of arm 14, but is slightly skewed. In this manner, the portion of fiber 34 immediately exiting adapter 16 is oriented at an oblique angle with respect to surface 18, and the resilient nature of optical fiber 34 causes it to bow near end 32. 20 This resilience also maintains end 32 in forcible abutment with the abrasive media on surface 18. Adapter 14 secures fiber 34 by means of an elastomeric gripping collet which may be conveniently attached to an implement which facilitates manual grasping. In Figure 3, a 25 polyurethane collet 42 (preferably having a durometer of about 50-80 Shore D) is inserted in an empty field mount ST ceramic connector 44 (after the collet has been threaded with the fiber). A bearing 46 is provided in hole 38 to allow rotation of fiber adapter 16 with 30 respect to arm 14. It should be understood, however, that adapter 16 does not rotate from an objective perspective, since it is arm 14 which is actually rotating. In other words, as the user is holding adapter 16 and indirectly pushing arm 14 to cause it to rotate, 35 adapter 16 moves in a circle back to its original position without rotating the fiber. Those skilled in the art will appreciate that, since this movement does

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not rotate the fiber, it does not induce any severe torsional stress which could damage or break the fiber.

In tool 10, and in each of the following embodiments of the present invention, there is relative 5 translational motion between the fiber adapter and the abrasive surface. In contrast, there is no translational movement between the adapter and abrasive disk of the prior art tool of Figure 2, even though they each individually rotate.

10 With tool 10, fiber preparation is reduced to a few simple steps. First, the fiber is stripped and cleaved using conventional methods. The cleaved fiber is next inserted into collet 42 of hand-held adapter 16; the length of fiber extending past adapter 16 may be measured 15 and set (as explained further below) if a specific bevel profile is desired. Adapter 16 is then inserted through bearing 46 in hole 38, positioning fiber end 32 against abrasive surface 18, as depicted in Figure 3. Arm 14 may be adjusted towards or away from surface 18 using set 20 screw 30, increasing or decreasing the amount the fiber is forced into surface 18. This adjustment affects the material removal rate as well as the included angle of the bevel.

25 The end face diameter d and the included angle α of the bevel (see Figure 1B) are the two main parameters of a beveled cylinder. These parameters are theoretically adjustable within a wide range, depending upon the size of the fiber. While tool 10 is somewhat limited in the ranges it can generate, the other 30 embodiments of the present invention described below may be used to produce wide ranges in beveling, from just lightly chamfering the edge, to grinding away nearly all of the end face except for the core. The bevel profiles illustrated in the drawings should therefore not be 35 construed in a limiting manner. For example, single mode fibers having an outside diameter of 125 μm (0.005") and a concentric, 7.6 μm (0.0003") diameter core were beveled

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with end face diameters ranging from 117 μm (0.0046") to 15.2 μm (0.0006"). Consistent repeatability was achieved to within $\pm 7.6 \mu\text{m}$ (0.0003"). Included angles for the 125 μm fibers ranged from 40° to 160°, although the range 5 of included angles for tool 10 was about 70° ± 10 °. The included angle is ultimately limited by the length of the fiber that can extend beyond the fiber adapter (in tool 10, this limit could be increased by making channel 20 deeper and adjusting the angle of adapter 16). With each 10 of the novel beveling tools described herein, the included angle can be controlled with excellent repeatability by accurately measuring the length of the fiber, such as by using a length setting fixture (not shown), similar to a ruler or a micrometer. Concentricity 15 of the end face of the fiber is maintained with respect to the outside diameter thereof.

Once adapter 16 is positioned, it is grasped between the thumb and forefinger and used to rotate arm 14 in a clockwise or counterclockwise motion. As 20 explained above, the fiber does not rotate as it is clamped in collet 42 secured to adapter 16 which is held by the user. This causes the entire fiber edge periphery to come into contact with abrasive media upon each complete rotation of the adapter arm, consequently 25 generating a conical bevel. As explained below, a specific number of arm rotations results in a particular end face diameter. After the desired number of rotations, adapter 16 is removed from arm 14, fiber 34 is removed from collet 30, and its end is cleaned using 30 conventional methods. Typical times spent rotating arm 16 range from three to five minutes. Insertion and removal of fiber 34 from collet 30, and cleaning of the fiber, take about a minute.

There are many benefits that can be obtained by 35 generating a bevel on the end of an optical fiber. The first is removal of end face surface imperfections caused by the cleaving process, particularly protruding defects

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at the edge which are common among cleaved fibers. Another benefit is the reduction of fiber end face separation as shown in Figures 1A and 1B. Yet another benefit is the reduction in end face surface area which 5 may improve physical contact between interconnected fibers. As noted above, this also allows smoother insertion into fiber optic devices. A related benefit is the improved edge strength of a beveled end face, since there is more supporting glass behind the edge, i.e., the 10 chamfer surface is frusto-conical. It should be understood that, while the beveling depicted in the drawings is generally conical, it need not be, e.g., the bevel profile could be rounded rather than straight.

Besides its ease and quickness of use, tool 15 10 has several other advantages. It is relatively lightweight and may be very compact, which facilitates transportation and storage. While the dimensions of tool 10 may vary considerably depending upon the particular applications, the following approximate dimensions are 20 deemed exemplary for beveling most conventional fibers used in telecommunications. Base 12 has a diameter of 5.1 cm (2"), and is 4.4 cm (1 $\frac{3}{4}$ ") high, from the bottom of base 12 to the top of adapter arm 14. Hole 38 is oriented at a 30° angle with respect to the normal of arm 25 14, i.e., with respect to surface 18.

Another advantage of tool 10 is that it is manually driven and requires no power source. Of course, means could be provided to motorize arm 14 (and prevent rotation of adapter 16), which would require that tool 10 30 also include a battery (or solar cells) for portability, or have a transformer or other means for converting standard 110 volt AC power. Other manual techniques could be used to drive arm 14, such as a spring wound motor, flywheel, turbine, etc.

35 Referring now to Figures 5-7, an alternative embodiment 50 of the present invention may be used to impart a bevel to an optical fiber. Tool 50 has a body

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52 which houses a rotating shaft supported by bearings in a manner similar to that shown in Figure 3. Body 52 also acts as a handle for the tool. A disk 54 is attached to body 52 at one end thereof, the disk having another 5 abrasive surface 56. An arm 58 adjacent disk 54 is attached to the rotating shaft inside body 52. Arm 58 has a hole therein to rotatably support an adapter 60 which is similar to adapter 14. As shown in Figure 6, a fiber held in adapter 60 will undergo the same bowing 10 toward its end where it contacts abrasive surface 56. A gage may be used to set the length of fiber extending beyond adapter 60 (the fiber set length). The amount of bowing of the fiber determines its included angle and the amount of force imparted, which determines the material 15 removal rate at the periphery. Arm 58 may be moved clockwise or counterclockwise. Operation is essentially identical to that with tool 10 and, as with tool 10, the fiber itself does not rotate or twist when using tool 50 since adapter 60 is free to rotate in arm 58, and it is 20 held by the user during movement of arm 58. With every complete rotation of the pivot arm, the complete end periphery of the fiber contacts the abrasive media. A conventional counter 62 may optionally be provided to track the number of revolutions of arm 58. Counter 62, 25 which has a reset button 64, is attached to body 52 by a bracket 66.

Figures 5-7 also depict the optional provision of a second fiber adapter 70 which may be seated in a second hole of arm 58. Adapter 70 may be used to impart 30 an angled end face to a fiber which has already been beveled. Angle polishing the end face of a fiber is known to minimize the adverse effects of back reflections which occur when a signal traverses the fiber end face. In this embodiment, the outer portion of abrasive surface 35 56 may be coarser for beveling (e.g., 5 μm grit), than the inner or central portion which is finer for polishing (e.g., 0.3 μm grit).

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After a fiber has been beveled as described above, it may be moved from the outermost (beveling) hole on arm 58 to the innermost (polishing) hole. In this regard, adapter 70 should be compatible with both of 5 these holes so that the user does not have to remove the fiber from one adapter and place it into another. The fiber set length is adjusted, however, when moving the adapter from the beveling hole to the polishing hole, by the difference in height where adapter 70 rests on arm 10 58. This adjustment (decreasing the fiber set length to slightly greater than the distance from the adapter to surface 56) changes the pitch of the fiber end, and results in removal of a portion of the end face rather than the periphery. In order to polish a flat angled 15 finish, it is necessary to fix adapter 70 to arm 58 (nevertheless, tool 50 can still, if desired, avoid actual rotation of the fiber by moving the entire body 52 and disk 54 in a circular motion while maintaining adaptor 70 fixed; such manipulation of tool 50 is 20 facilitated by its hand-held nature). Adapter 70 may be fixed on arm 58 by any convenient means, such as keying it with a spline which mates with a corresponding groove formed in the polishing hole of arm 58, or providing other mechanical polarizing means. A ring or bushing may 25 be placed about adapter 70 to be gripped with fingers if arm 58 is to rotate while body 52 is stationary.

The outermost hole of arm 58 could also be used to polish an angled end face, but the present invention is primarily directed to a fiber beveling tool and so, in 30 the preferred embodiment of tool 50, the outermost hole in arm 58 is not design for fixed (keyed) attachment. Use of the optional polishing adapter could also be designed into a modified version of tool 10.

In the embodiment of Figures 3 and 4, the 35 effective orientation of surface 18 (i.e., the orientation of the tangent plane defined at any point of contact between fiber 34 and cylindrical surface 18) is

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parallel to the axis of rotation of arm 14. In contrast, tool 50 orients abrasive surface 56 perpendicular to the axis of rotation of arm 58. Those skilled in the art will appreciate that either of the tools 10 or 50 could 5 alternatively provide an abrasive surface 18 which was oriented at a non-orthogonal angle but still not parallel to the axis of rotation of arm 14, i.e., at an oblique angle. For example, a frusto-conical surface 68 could be provided as shown in Figure 8, wherein the axis of the 10 cone coincides with the rotating shaft. In a modified version of tool 10, channel 20 could be formed in an insert element which is removably positioned in the upper end of base 12, and a plurality of such inserts interchangeably used to provide abrasive surfaces at 15 different angles. There are, however, some advantages in using flat disk 54 to support the abrasive surface. There are more commercially available abrasive pads which are the appropriate size and shape for a disk, and they are easily replaced. There is also more useable abrasive 20 media, particularly if the length arm 58 is adjusted to use different ring areas over the radius of the pad.

As with tool 10, tool 50 is both lightweight and compact. While its dimensions may also vary, the following approximate dimensions are considered exemplary 25 for tool 50. Its overall length (from the tip of counter 62 to the top of arm 58) is 23 cm (9"), with an additional 2.5 cm (1") for the fiber adapter. The abrasive disk is 10 cm (4") in diameter.

Another hand-powered fiber beveling tool made 30 in accordance with the present invention is shown in Figures 9 and 10. Tool 72, however, is intended for bench use. It includes a base 74 having another rotatably mounted shaft 76, with another arm 78 attached to shaft 76. Operation of tool 72 is similar to that of 35 tool 50. Tool 72 may be designed for use with a different type of adapter 80 depicted in Figure 11, which grips the fiber more securely than adapter 16. Different

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adapters, each having the same outer dimensions, may be used for different fibers, i.e., 250 μm and 900 μm fibers, or even fiber ribbons, with only the inner fiber passageway being different. In this regard, those 5 skilled in the art will appreciate that the beveling tools described herein may be used to bevel multi-fiber ribbons as well as discrete fibers. A fiber ribbon will not flex (bow) in the identical manner as a discrete fiber (i.e., it is stiffer along its transverse 10 dimension), but a satisfactory bevel may still be formed, although it may be oval about the periphery rather than perfectly circular. In this manner, the different adapters can fit into a common nest in arm 78. Of course, adapter 80 could also be used with the other 15 beveling tools described herein.

Adapter 80 has a body 82 with a collet portion 84 and a cap 86 movable on the collet between a raised, open position and a lowered, closed position. An inwardly extending annular flange 88 formed in one end of 20 cap 86 provides a friction fit for both positions, by seating in one of two grooves on either side of an annular ridge 90 formed at the juncture of collet 84 and body 82. In the preferred embodiment, cap 86 moves about 2 mm (0.08") between the open and closed positions. Cap 25 86 and body 82 are constructed of any resilient material, preferably a polymer such as DELRINTM, an acetal polymer available from E.I. duPont de Nemours of Wilmington, Delaware. Collet 84 has a hole therethrough for receiving the fiber, and the entrance end of collet 84 30 has several slots extending from edge to edge through the fiber hole, approximately one-third the length of the adapter 80. The outer surface of collet 84 and the inner surface of cap 86 are conical or tapered, so that moving cap 86 to its lowered position creates a confining 35 pressure about collet 84, collapsing it partially about the slots, thereby compressing the fiber and securing it in the adapter. Closing adapter 80 does not affect the

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position of the fiber which is important since the fiber set length is measured with a gage prior to closing. In an adapter for 250 μm fiber, the fiber hole through collet 84 and body 82 is preferably about 280 μm (0.011") 5 in diameter. An adapter for 900 μm fiber would have a hole about 1 mm (0.04") in diameter. The hole through a fiber ribbon adapter (e.g., for a 12-fiber ribbon) would be more of a slot, with a width of about 280 μm (0.011") and a length of about 3.2 mm (0.125"). Of course, cap 86 10 also has a hole therethrough, preferably tapered, for insertion of the fiber and alignment with the fiber passageway in collet 84. The overall height of adapter 80 is approximately 3.2 cm (1 $\frac{1}{4}$ "); the lower body has a diameter of about 0.6 cm ($\frac{1}{4}"), and the cap has a diameter 15 of about 1 cm (0.4"), with a flange width of 1.5 cm (0.6"). The following approximate dimensions are considered exemplary for tool 72. Base 74 is 10.8 cm (4 $\frac{1}{4}$ ") in diameter, and 5 cm (2") high, although the overall height (from the bottom of base 74 to the top of 20 the cam clamp mentioned below) is 9.9 cm (3.9"). Arm 78 is 10.5 cm (4.13") long.$

A flange 92 is formed on body 82 as a reference for the fiber set length, and to attach adapter 80 on arm 78. In the preferred embodiment of Figures 9 and 10, 25 adapter 80 is secured to arm 78 by spring-loaded locking clamps 94. Clamps 94 pivot about shoulder screws 96 and are adjacent a plate 98, forming part of arm 78, having a slot 100 therein defining a track for adapter 80. With this construction, an adapter 80 may be inserted into 30 clamps 94 by sliding the adapter along plate 98, in slot 100 (from the left side of Figure 9), to nest area 102. By sliding adapter 80 onto arm 78 in this manner, the end of the fiber slides onto and across abrasive surface 104. This minimizes possible damage to the fiber end face 35 which might otherwise occur if the adapter were moved downward onto nest area 102, and which would require re-cleaving.

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When adapter 80 is in nest 102, the ends of clamps 94 overlie flange 92 and restrict upward motion (accidental removal) of adapter 80, although there is sufficient clearance between the clamps and flange 92 to 5 allow rotation of adapter 80 as arm 78 rotates. After the fiber has been beveled, adapter 80 may be upwardly removed by squeezing the handle portions of clamps 94, thereby retracting the clamps from over flange 92.

Another optional feature of tool 72 is the 10 ability to index the adapter arm, i.e., adjust its length, which allows greater use and life of the abrasive sheet on surface 104. In the preferred embodiment of tool 72, this is achieved by machining multiple slots 106 in an extension 108 of arm 78, the slots being 15 perpendicular to the axis of shaft 76. A pin 110 smaller in diameter than slots 106 is pressed though shaft 76 to locate arm 78 in one of many indexed positions. A cam clamp 112 attached to the top of shaft 76 has a radius cam surface 114 which applies and releases clamping 20 forces to adapter arm 78 through a bushing 116. This mechanism allows quick indexing of arm 78. Cam clamp 112 is shown in its clamping position, with the release 25 position indicated with dashed lines. A pin 118 retains cam clamp 112 on shaft 76, but can be removed to quickly and easily disassemble clamp 112, bushing 116 and arm 76 from shaft 76 to permit changing of the abrasive sheet at surface 104.

In a variation (not shown) of tool 72, the 30 abrasive media is formed on a disk which may also rotate about shaft 76. The disk is connected by a gear train to shaft 76, such that movement of arm 78 causes counter-rotation of the disk, speeding up beveling time.

With further reference to Figures 12-14, a 35 motorized embodiment 120 of the fiber beveling tool of the present invention is presented. Tool 120 uses the same principles as the foregoing tools to bevel the fiber end without twisting the fiber. Tool 120 includes a base

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122 housing a motor 124 (preferably having a 280 rpm output at 12 volts). Base 122 should also house a power source for motor 124, i.e., a battery or a 110 volt to 12 volt converter (not shown). A coupling 125 attaches the 5 shaft 126 of motor 124 to a crank arm 128. The upper end of crank arm 128 is rotatably mounted to a platter 130 by means of a bearing 132 inserted in a socket 134 formed in the lower surface of platter 130. Movement of platter 130 is limited by a sliding plate 136 having a generally 10 rectangular cutout 138 therein, the cutout surrounding socket 134; the outer wall of socket 134 is accordingly generally square in shape. Movement of sliding plate 136 is in turn limited by slide retainers 140, which allow 15 sliding movement of plate 136 in only one direction, and by the inner walls 142 of base 122. In this manner, platter 130, which supports the abrasive media, may move in an orbiting fashion about the axis of shaft 126, but platter 130 does not necessarily rotate due to bearing 132. Crank arm 128 draws a circle about 3.8 cm (1.5") in 20 diameter.

A cover assembly 144 shown in Figure 13 overlies base 122 and receives a plurality of adapters 80. Cover assembly 144 includes a cover plate 146 having a plurality of slots 148 similar to slot 100 in arm 78 of tool 72. Cover plate 146 is generally circular and slots 148 extend radially thereon from the periphery of plate 146 toward the center thereof, where each slot terminates in a nest area 150 near the center of plate 146. In the preferred embodiment of tool 120, cover plate 146 has 25 eight slots, and may thus simultaneously bevel eight different fibers (more or less slots could be provided). Adapters 80 may be secured in nest areas 150 by means of a fiber adapter lock 152 rotatably attached to plate 146 at the center thereof. Fiber adapter lock 152 has a 30 plurality of spokes or fingers 154 which extend toward nest areas 152, but the fingers are spaced widely enough 35 to allow upward removal of adapters 80 when lock 152 is

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in its open position. By slightly twisting lock 152 to its closed position, one of the fingers 154 overlies each nest area, securing the adapters by retaining flanges 92 thereof. As with the foregoing embodiments, the fibers 5 do not rotate during the beveling process, i.e., fiber adapter 80 does not rotate when platter 130 is orbiting. Bevels were generated on fibers within 15 seconds with this tool.

The following approximate dimensions are 10 considered exemplary for tool 120. Base 122 is 22 cm (8.6") in diameter, and 16.8 cm (6.6") high. Cover 146 is 18.7 cm (7.35") in diameter. The overall height of tool 120 (from the bottom of the base to the top of the cover) is 21 cm (8.4"). There is a 6.4 cm (2½") spacing 15 (centerline to centerline) between adjacent fiber adapters.

Another motorized embodiment 160 of the fiber beveling tool of the present invention is illustrated in Figure 15. Tool 160 is very similar to tool 120, and 20 includes a base 162 housing a motor 164 which may be coupled, via reduction gears, to a shaft 166. Base 162 of tool 160 may also house conventional components (not shown) related to motor 164, such as a battery, speed selector switch, and timer circuit. Rather than using a 25 sliding cam plate, however, tool 160 induces orbiting motion of the abrasive media platter 168 using a pulley system. Shaft 166 is fixed to a crank arm 170 which has a hole therein at one end for receiving the platter axle 172, and a counterweight at the other end. Axle 172 is 30 free to rotate in the hole due to the presence of a bearing 174 located therein. The lowest end of axle 172 passes through a pulley 176 which is coupled by a flexible belt (not shown) to another pulley 178. Pulley 178, which rotatably receives motor shaft 166, is fixed 35 to base 162 by any convenient means, such as screws. In this manner, as motor shaft 166 rotates, crank arm 174 causes platter 168 to orbit. The diameter of pulley 178

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is slightly shorter than the diameter of pulley 176 whereby platter 168 will rotate several degrees upon completion of each orbit, ensuring that the fiber end will consistently be exposed to unused abrasive media, 5 extending the life of the abrasive sheet.

Figure 15 also illustrates the alternative use of guide rails 180 to retain the fiber adapters 80 on the cover 182 of tool 160. As with tool 120, cover 182 may have a plurality of slots therein for receiving the 10 adapters. Guide rails 180 overlap a portion of the slots, with sufficient clearance to receive flange 92 of adapter 80. This prevents the accidental upward movement of the adapter during insertion which might lead to fiber end face contact with the abrasive surface, causing 15 damage to the end face. Guide rails 180 may be provided with integral leaf springs at the adapter nest areas to forcibly secure the adapters during the beveling operation.

The following approximate dimensions are 20 considered exemplary for tool 160. Base 162 is 21.6 cm (8.5") square, and its overall height is 13.5 cm (5.3"). The distance from the abrasive surface to the bottom of 25 the fiber adapter (when it is fully inserted into the slots in cover 182) is 7.65 mm. A user of tool 160 may generate a bevel with a desired included angle α and a desired end face diameter d for a glass fiber by adjusting the fiber set length and rotating arm the number of turns indicated in the following table. These data were gathered using a 250 μm buffered fiber (with a 10 mm 30 strip length) and Imperial Lapping Film with a 1.5 μm grit (diamond abrasive). Platter 168 rotated at 240 orbits per minute.

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	SET LENGTH	BEVEL TIME	END FACE DIAMETER ($\pm .0003$)	BEVEL INC. ANGLE ($\pm 10^\circ$)
5	8MM	15 SEC.	30.48 μm (.0012")	150 $^\circ$
	9MM	15 SEC.	45.72 μm (.0018")	95 $^\circ$
	10MM	20 SEC.	38.1 μm (.0015")	75 $^\circ$
	11MM	20 SEC.	50.8 μm (.002")	65 $^\circ$
	12MM	30 SEC.	43.18 μm (.0017")	58 $^\circ$
	13MM	30 SEC.	63.5 μm (.0025")	45 $^\circ$

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Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as 15 alternative embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the spirit or scope of the present invention as defined in the appended claims.

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CLAIMS:

1. A device for removing a portion of the end of an optical fiber along its periphery, comprising:
 - a base member;
 - 5 adapter means for releasably securing a length of the fiber near its end, said adapter means allowing adjustment of the length;
 - 10 an arm member rotatably mounted to said base member, defining an axis of rotation, said arm member having means for releasably holding said adapter means;
 - 15 an abrasive surface formed on said base member proximate said arm member, said abrasive surface being oriented at a non-orthogonal angle with respect to said axis of rotation of said arm member.
- 15 2. The device of Claim 1 wherein said abrasive surface is oriented at an oblique angle with respect to said axis of rotation of said arm member.
- 20 3. The device of Claim 1 wherein said abrasive surface is parallel with said axis of rotation of said arm member.
- 25 4. The device of Claim 1 wherein said arm member has an effective length, and further comprising means for adjusting said effective length of said arm member.
5. The device of Claim 1 wherein said adapter means is rotatably attached to said arm member.
- 30 6. The device of Claim 1 further comprising a shaft member rotatably mounted on said base member, said arm member being affixed to said shaft member.
- 35 7. The device of Claim 1 wherein:
rotation of said arm member defines a plane;
said adapter means includes an end portion; and
said arm member has a hole therethrough for receiving said end portion of said adapter means, said hole being skewed with respect to said plane defined by said arm member.
8. The device of Claim 1 wherein said abrasive

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surface is formed along a wall of a circular channel formed in one end of said base member.

9. The device of Claim 1 wherein said adapter means includes an elastomeric collet having a slot 5 therein for receiving the fiber.

10. The device of Claim 6 wherein said arm member is releasably affixed to said shaft member.

11. The device of Claim 7 wherein said hole has bearing means therein for rotatably supporting said end 10 portion of said adapter means.

12. The device of Claim 8 wherein said wall of said channel is generally cylindrical.

13. The device of Claim 8 wherein said wall of said channel is generally conical.

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14. A fiber beveling tool comprising:

a base having a bottom end and a top end, said bottom end being generally flat, and said base having a circular channel formed therein at said top end thereof,
5 said circular channel having a wall supporting abrasive media, and said circular channel defining an axis;

a shaft;

10 bearing means rotatably mounting said shaft on said base, the location of said shaft generally coinciding with said axis of said circular channel;

adapter means for releasably securing a length of an optical fiber near its end, said adapter means having an end portion; and

15 an arm releasably affixed to said shaft, said arm having a hole therein for receiving said end portion of said adapter means.

15. The tool of Claim 14 wherein said adapter means includes an elastomeric collet having a hole therethrough for receiving the fiber.

20 16. The device of Claim 14 wherein:

rotation of said arm defines a plane; and

25 said hole in said arm is skewed with respect to said plane defined by said arm member.

17. The device of Claim 14 wherein said arm has an effective length, and further comprising means for adjusting said effective length of said arm.

25 18. The device of Claim 14 wherein said hole has means therein for rotatably supporting said end portion of said adapter means.

30 19. The device of Claim 14 wherein said wall of said channel is generally cylindrical.

20. The device of Claim 14 wherein said wall of said channel is generally conical.

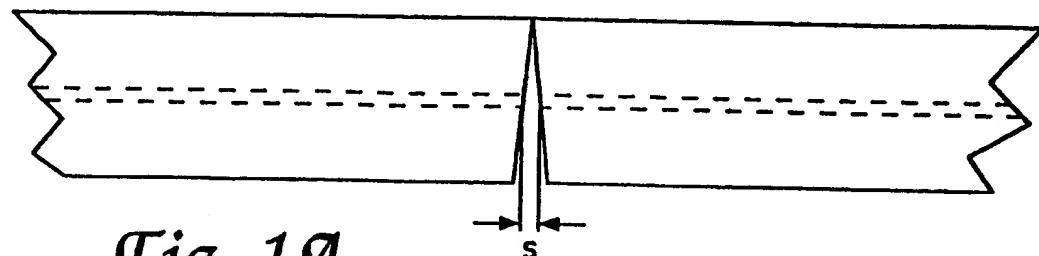


Fig. 1A

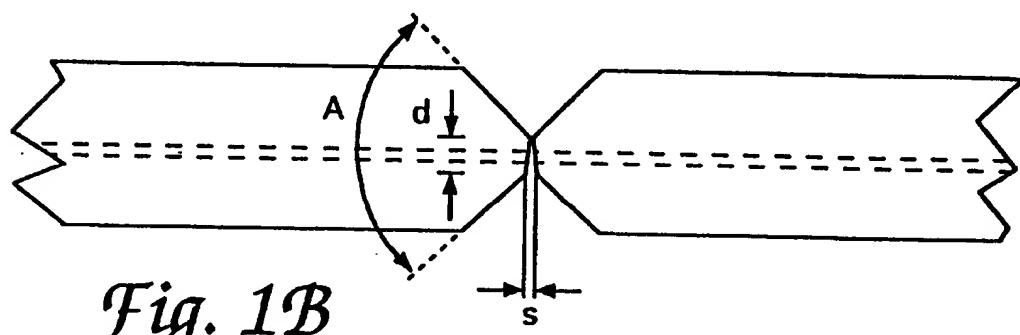
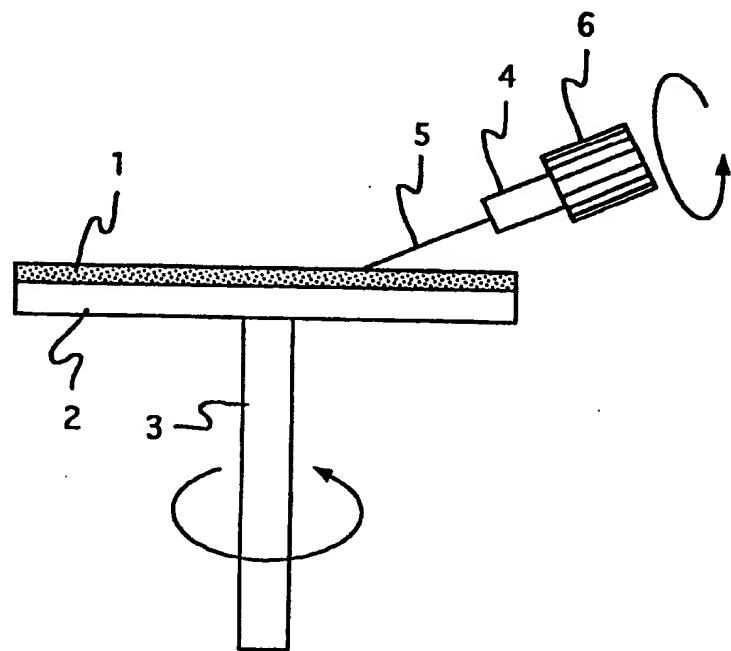


Fig. 1B

Fig. 2
PRIOR ART

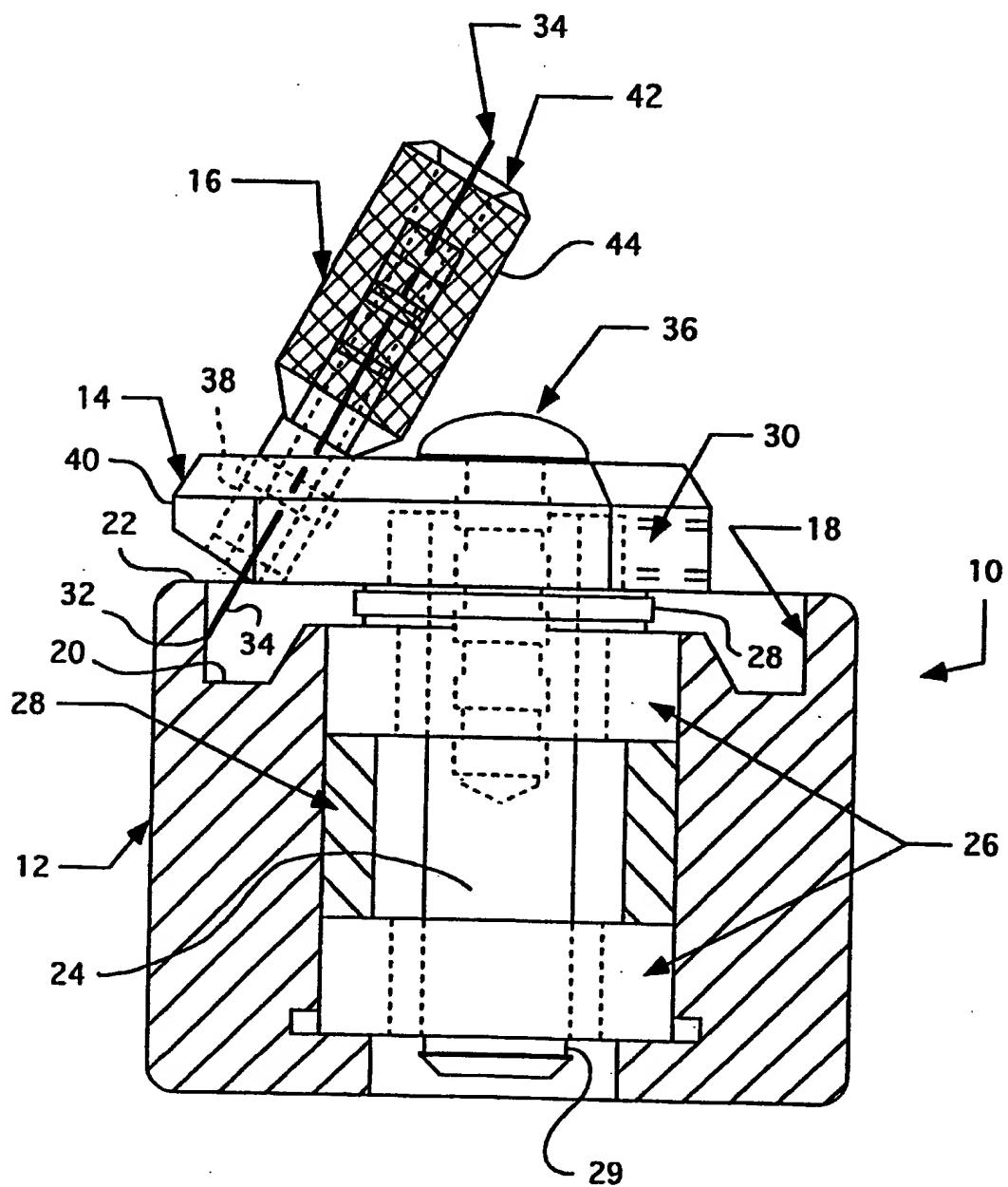


Fig. 3

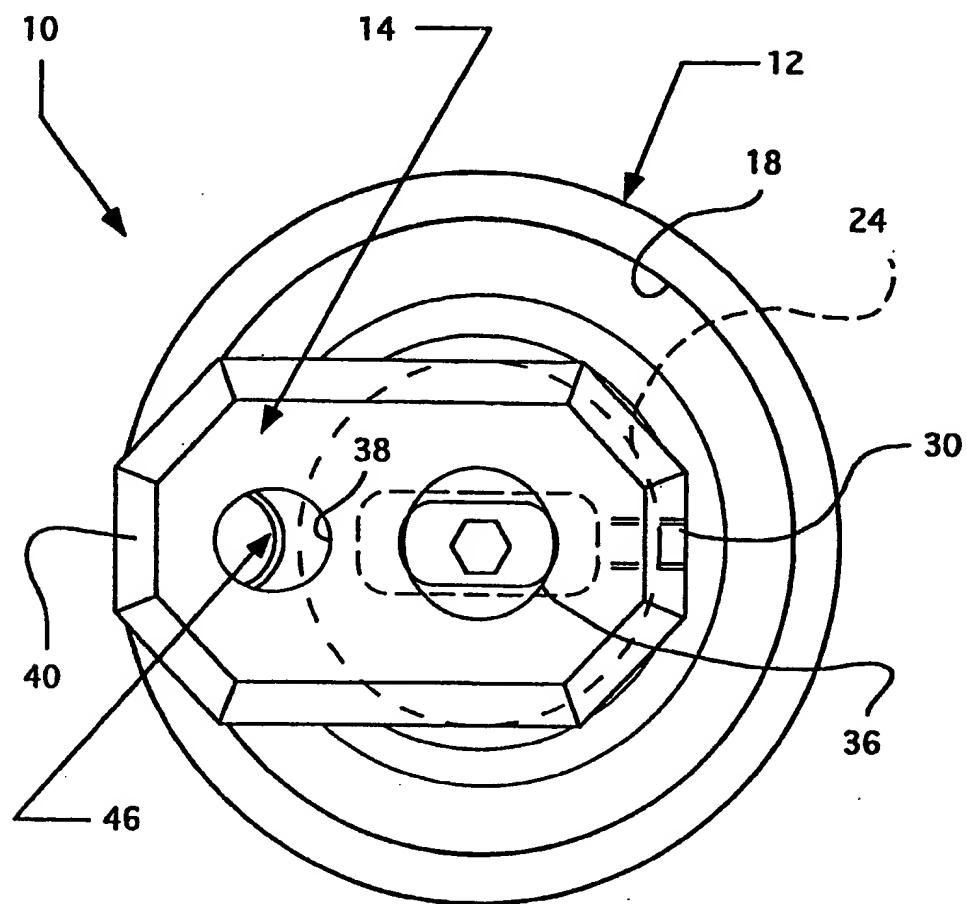


Fig. 4

Fig. 7
64 -

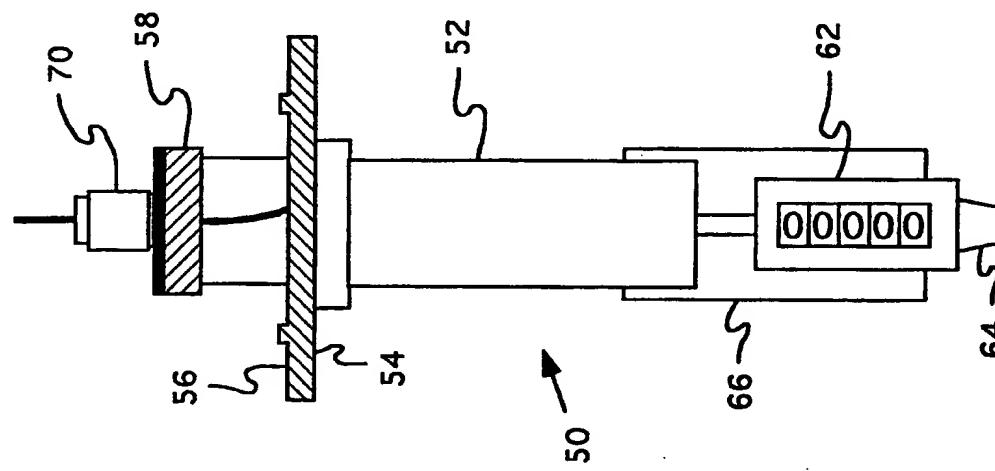


Fig. 6
64 -

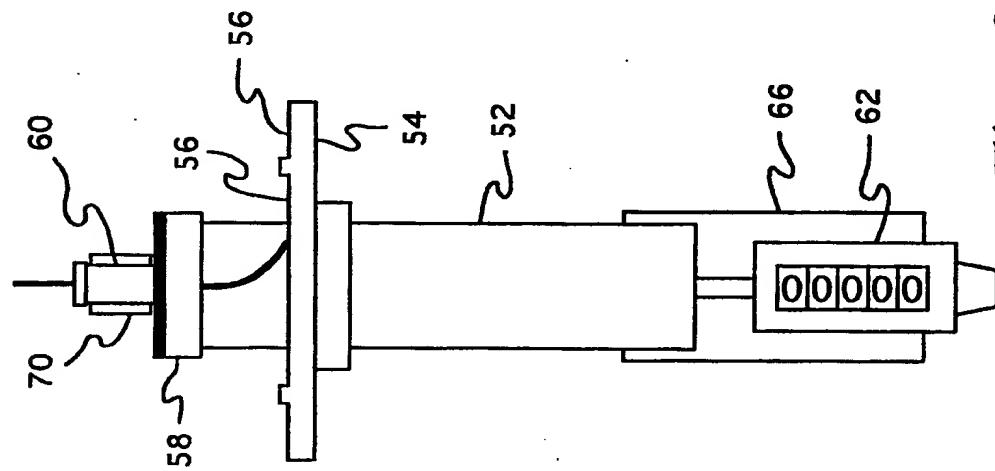
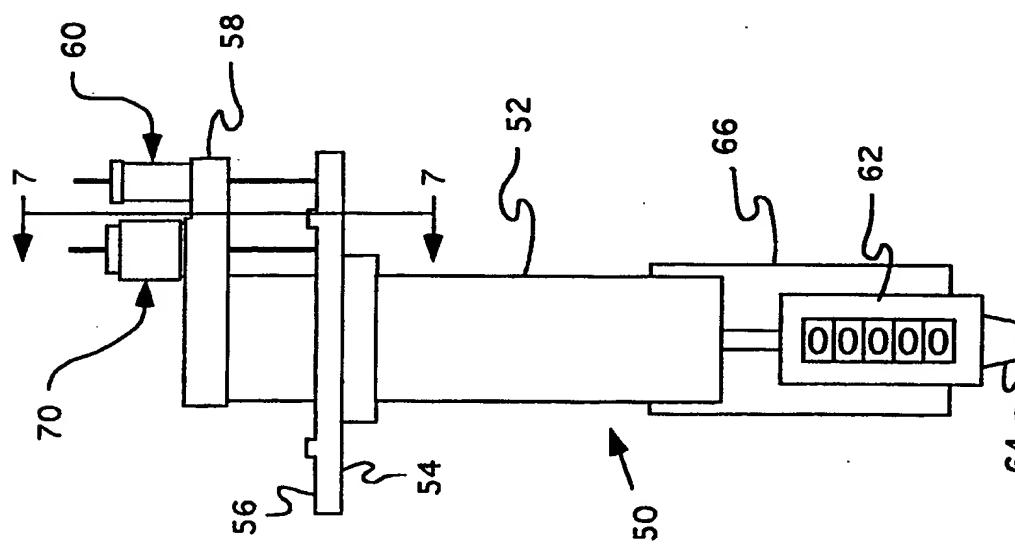


Fig. 5
64 -



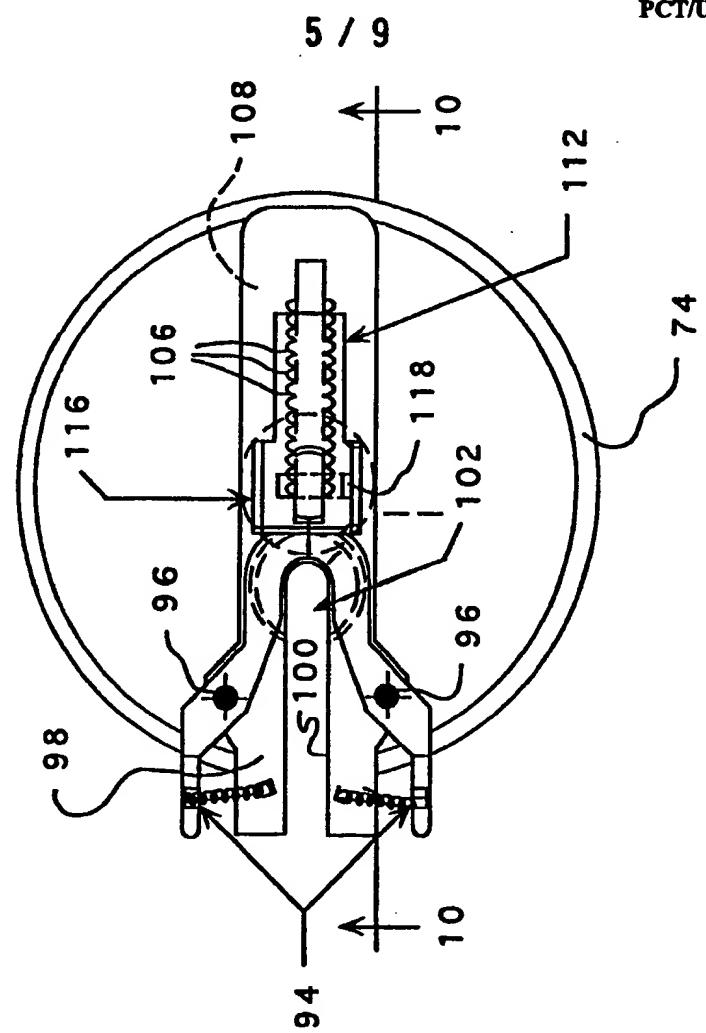
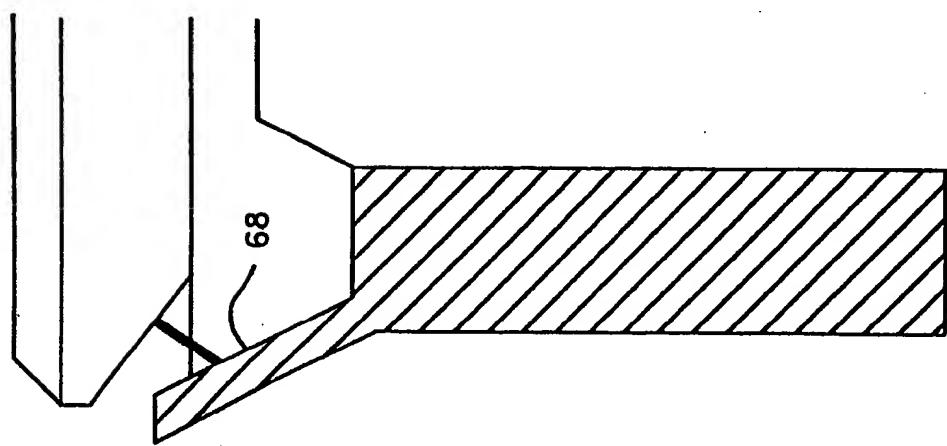


Fig. 9



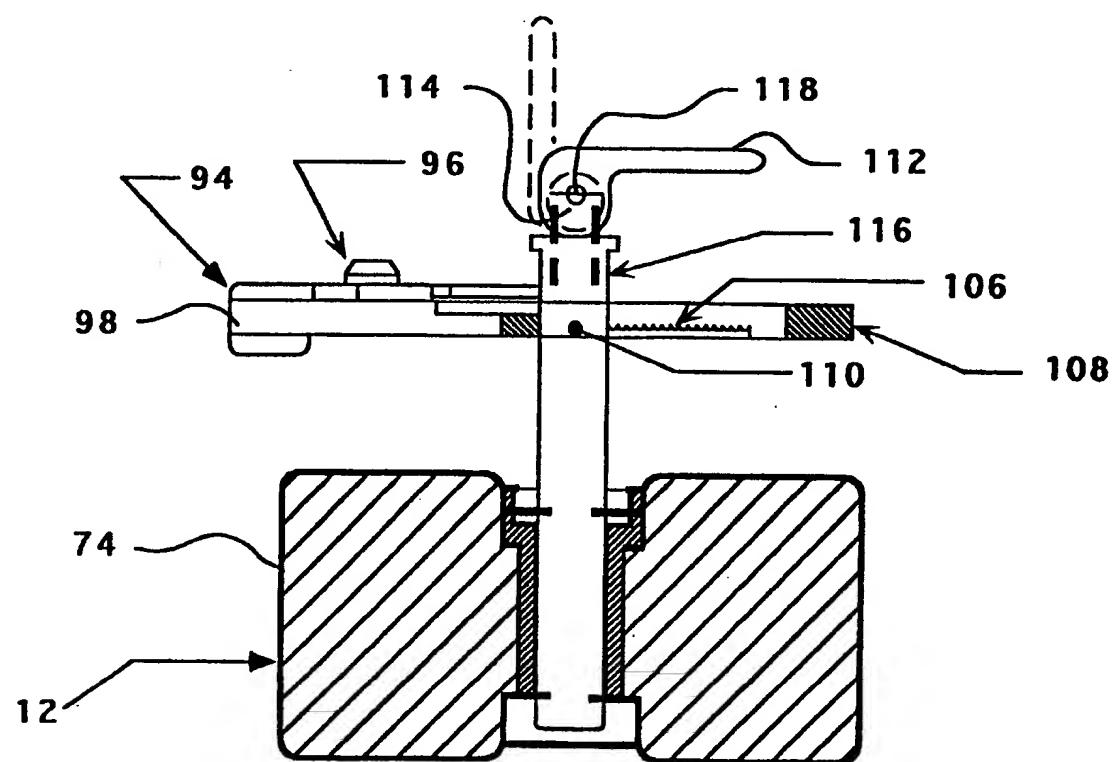


Fig. 10

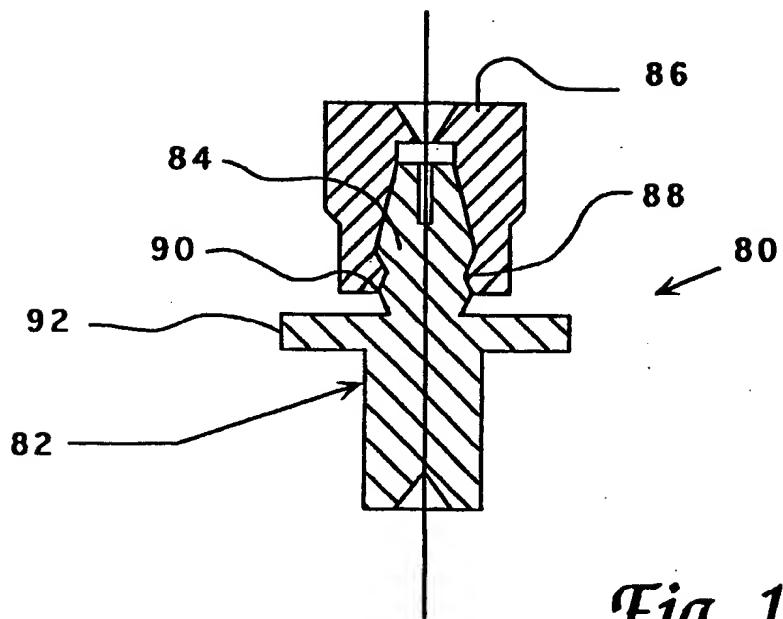


Fig. 11

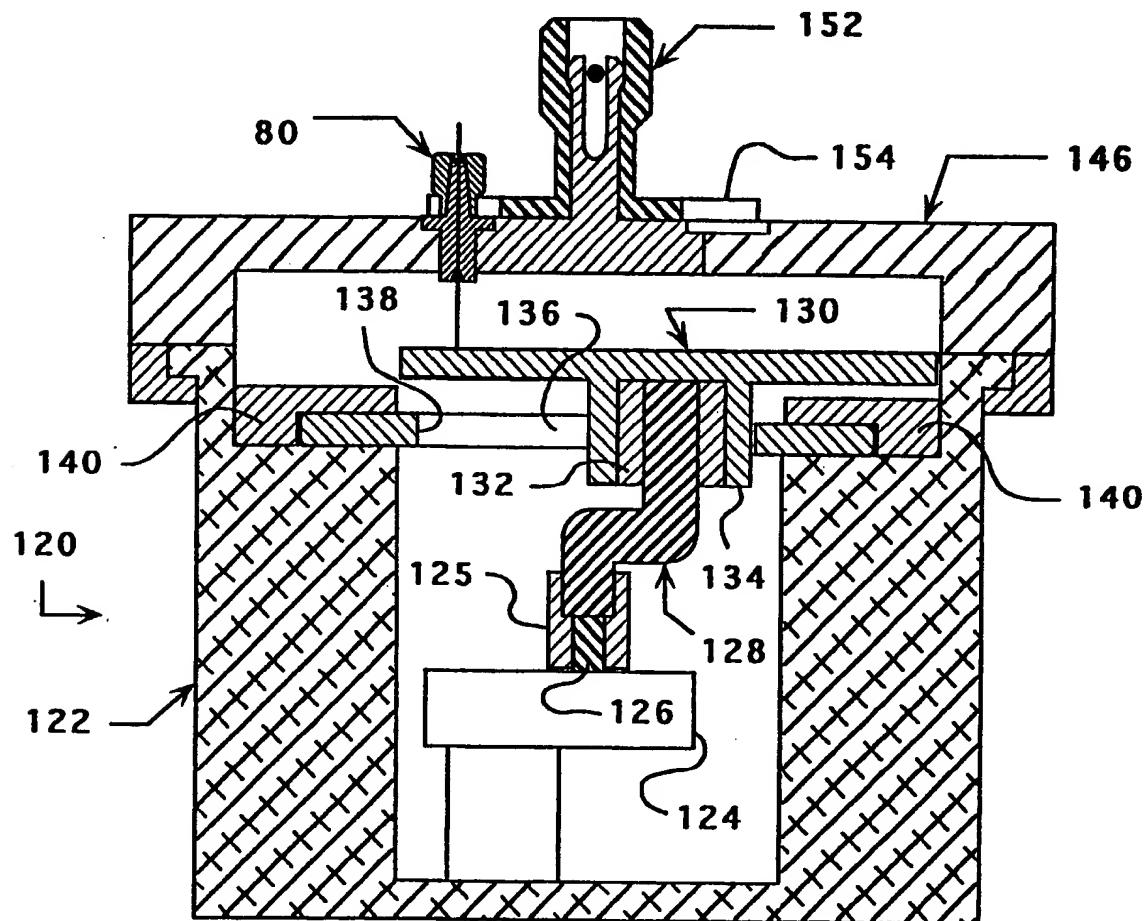


Fig. 12

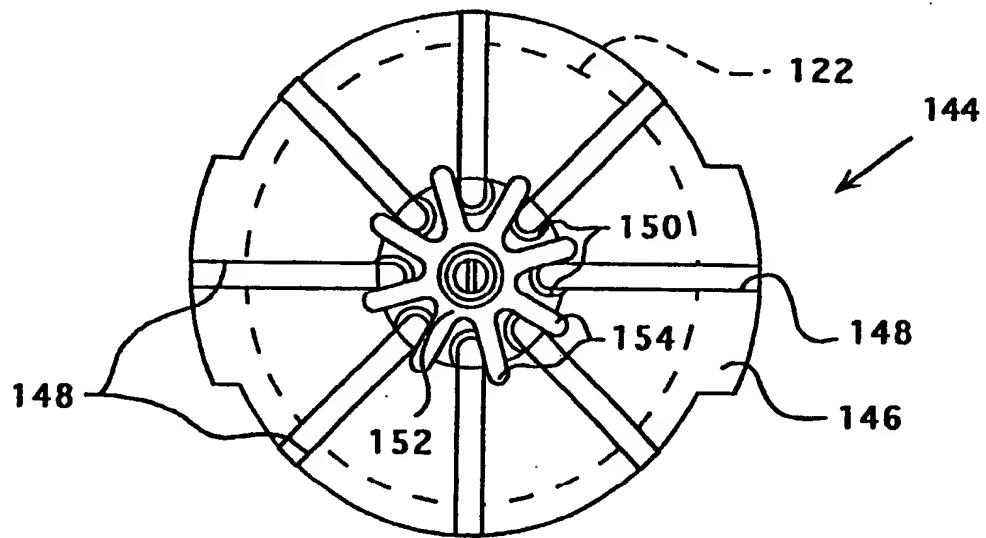


Fig. 13

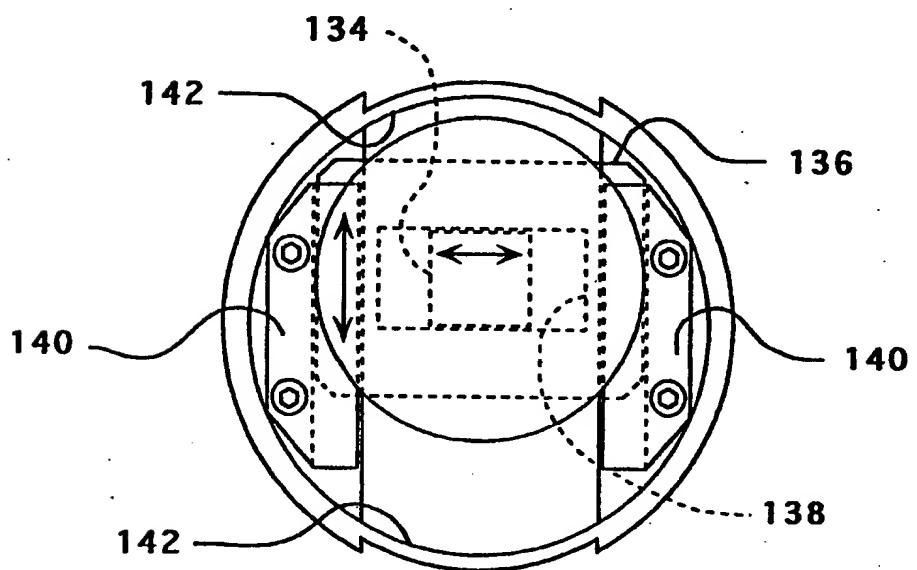


Fig. 14

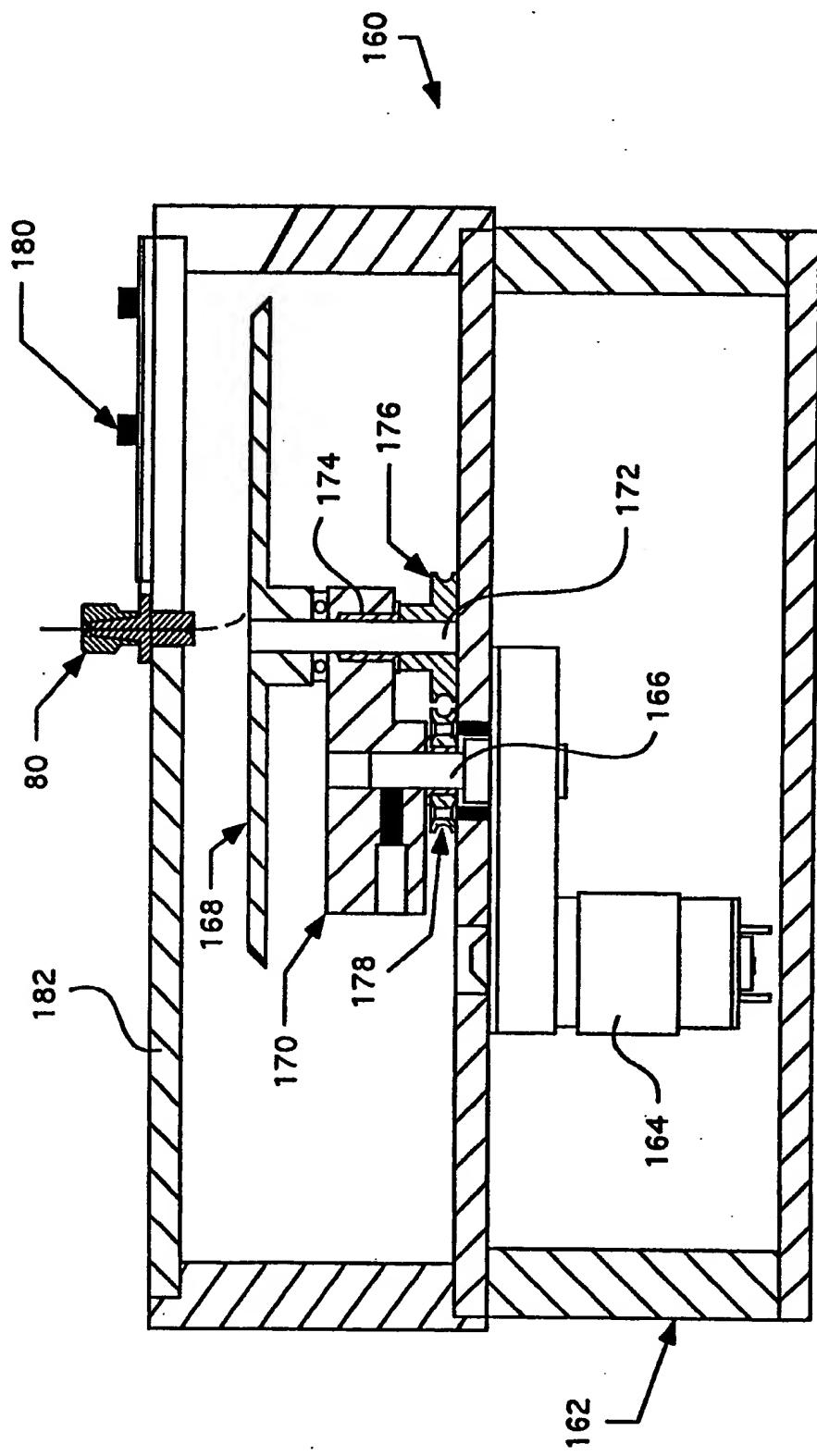


Fig. 15

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 94/08605

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24B19/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 294 650 (TEKTRONIX INC.) 14 December 1988 see claims; figures ----	1,14
A	WO,A,88 04217 (ENGIS LTD.) 16 June 1988 see page 8, line 17 - page 9, line 16; figures 6,7 ----	1,14
A	EP,A,0 529 939 (TOTOKU ELECTRIC CO. LTD.) 3 March 1993 see page 7, column 11, line 17 - line 57; figure 12 ----	1,14
A	WO,A,90 09207 (SIMONS R.) 23 August 1990 ----	

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

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- *O* document referring to an oral disclosure, use, exhibition or other means
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T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

1

Date of the actual completion of the international search

Date of mailing of the international search report

28 November 1994

19.12.94

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Authorized officer

Eschbach, D

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Appl. No.

PCT/US 94/08605

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0294650	14-12-88	US-A- JP-A-	4818263 1071659	04-04-89 16-03-89
WO-A-8804217	16-06-88	AU-A-	1040388	30-06-88
EP-A-0529939	03-03-93	JP-A- US-A-	5181034 5245684	23-07-93 14-09-93
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